High-Speed Oven Energy Use Field Monitoring for the Commercial Foodservice Industry

Final Report

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Executive Summary

The primary objective of this study was to characterize the savings opportunities associated with high-speed ovens and create a measure package that can effectively leverage those opportunities to guide efficient market utilization of the technology. High-speed ovens are a rapidly growing appliance category, but the data needed to properly characterize high-speed oven current market usage and prospective energy savings potential when optimally integrated into a foodservice operation is still significantly lacking. To fill this data gap and develop a comprehensive outlook on the high-speed oven market in California, Frontier Energy generated data throughout this study through a mixture of market analysis and field data acquisition.

To collect market data, Frontier Energy interviewed numerous manufacturers, representative groups, designers, consultants, and associations about the current status of and prospective future paths for the California high-speed oven market. The unanimous sentiment was one of continued growth, with the market expected to grow 10 percent to 20 percent over the next two years. With continued manufacturer innovation and increasing market awareness for the optimal applications for this technology, high-speed ovens are expected to revolutionize the convenience store sector and continue to expand their footprint in quick-service applications. This will be especially true for large chains with high-standardized food products, a setup that fully maximizes the strengths of high-speed cooking technologies. Frontier estimates a current inventory of about 23,000 high-speed ovens in the state of California.

To collect field data, Frontier monitored oven energy consumption and usage patterns at eleven field sites, which included energy data for ten high-speed ovens and one gas oven. Operational data demonstrated significant variation across use cases for high-speed ovens, with highly varying hours of operation, average daily energy consumption, and duty cycles. For typical quick-service applications, average daily energy use varied between 13.1 kilowatt-hours per day to 3.3 kilowatt-hours per day, and the high-speed ovens' hours of operation spanned from 14.4 hours per day to 4.2 hours per day. Despite large variations between high-speed ovens at different quick service restaurant (QSR) locations, most high-speed ovens operated consistently on a day-to-day basis, with an overall average 8.9 kilowatt-hours per day in energy consumption across 9.3 hours of operation. Among the surveyed 24-hour convenience stores, average daily energy consumption was much higher at an average 26.5 kilowatt-hours per day, with individual stores even going as high as 36.2 kilowatt-hours per day of daily energy consumption.

Frontier replaced the existing appliances at three sites, upgrading the gas oven and two existing high-speed ovens to the newest generation of energy efficient electric high-speed ovens. Frontier developed an energy model from the culmination of laboratory testing data and the real-world operational field site data collected from this project to estimate overall potential for high-speed ovens within California. Using the operational hours from the evaluated sites and the laboratory test results from standardized testing of high-speed ovens under the ASTM International F2238 Standard Test Method for Performance of Rapid Cook Ovens (ASTM International 2020), Frontier estimated 28 percent energy savings when converting from a standard high-speed oven to an energy efficient high-speed oven, equivalent to 2,354 kilowatt-hours per replaced unit. With a current inventory of about 23,000 high-speed ovens in California, Frontier estimates that the statewide energy savings

potential for high-speed ovens may be around 5.4 terawatt-hours per year, assuming 10 percent of the existing high-speed oven inventory are older units ready for replacement.

Frontier also reviewed market pricing data to estimate an incremental measure cost of $2,979 for upgrading from a baseline high-speed oven to an efficient one. Efficient high-speed ovens were defined as ovens tested via ASTM F2238-20 to have a cooking efficiency greater than or equal to 39 percent and an idle rate of less than or equal to 1.00 kilowatt, with all other ovens that do not meet that criteria—or have not been tested at all—assumed to be baseline. With a calculated 2,354 kilowatt-hours per year of savings per high-speed oven, and assuming an average commercial cost of electricity in California of 30 cents per kilowatt-hour, Frontier estimates a return on investment of 4.2 years for a high-speed oven replacement at this time. The lab, field and market data were combined into a draft measure package for submission to the California Technical Forum (CalTF).

This research covered the use case of replacing a high-speed oven and provides limited insight into potential cases for fuel-switching with a gas convection oven, but it does not cover the full gamut of potential replacement cases. Additionally, the three replacements conducted during the project did not replicate the theoretical savings represented by the energy model. Follow up research on real-world replacements for high-speed ovens and other countertop appliances is recommended for more comprehensive support of energy savings projections.

Abbreviations and Acronyms

Acronym	Meaning
CalTF	California Technical Forum
CEC	California Energy Commission
CFS	Commercial food service
Combi	Combination oven
EE	Energy efficiency
hr	Hour
IOU	Investor-owned utility
kW	Kilowatt
kWh	Kilowatt-hour
NAFEM	North American Association of Food Equipment Manufacturers
QSR	Quick service restaurant
ROI	Return on investment
TWh	Terawatt-hour
W	Watts

Tables

Introduction

Frontier Energy captured real-world field data on high-speed ovens to characterize their energy and cooking use profiles, with the goal of identifying potential savings opportunities and creating a measure package that can effectively leverage those opportunities to guide efficient market shifts. The project was composed of the following key steps:

- Conduct market research with key stakeholders to develop comprehensive picture of the current high-speed oven market in California.
- Monitor energy consumption of ovens at 11 commercial food service (CFS) sites, including 10 electric high-speed oven sites and one gas convection oven site.
- Replace ovens at three of the sites (including the gas convection oven site) with efficient high-speed ovens.
- Characterize quantitative and qualitative effects of replacement at the three sites.
- Summarize research in comprehensive report.
- Generate high-speed oven draft measure package.
- Distribute research findings to broader CFS community to spread awareness and catalyze market change.

Background

High-speed ovens represent a growing market that has continued to gain traction in the past decade, with major chains like Starbucks and Dunkin' Donuts incorporating the technology into their business models. High-speed ovens provide businesses with a way to quickly heat food while still maintaining the textural components that are typically lost with a microwave, which previously served as the cornerstone appliance for quick heating. With the ability to serve hot food quickly while maintaining taste and quality, high-speed ovens have experienced appreciable market gain over the past few years.

High-speed ovens present a complex market, but with continued manufacturer innovation and increasing market awareness for the optimal applications for this technology mean it will likely continue to expand. Research into high-speed ovens and their place in the market has increased accordingly as well. Frontier Energy's 2021 report, *Electric Plug Load Savings Potential of Commercial Foodservice Equipment* (Ruan, Finck and Livchak 2021), introduced an extensive effort towards categorizing high-speed oven technology types and cooking performance. The report outlined the state of the market in 2021 and generated substantive lab data to characterize how high-speed oven energy consumption could vary throughout different cooking operations with different food products. Energy Solutions' 2022 report, *Rapid Cook Oven Measure Study* (Booth 2022), expanded further on the market segments where high-speed ovens were gaining traction, outlining key large operators adopting the technology. This project is the natural progression of those two reports, focusing on characterizing the field data component to pair with the existing lab and market data and creating a measure package through the culmination of all high-speed oven research. This may result in greater understanding of high-speed ovens while hopefully diversifying the markets for which the strengths of the technology are being properly utilized. Sectors such as convenience stores represent significant opportunities that have not yet been fully capitalized, whether that be from improving current foodservice operation or expanding available services.

Objectives

The primary objective of this study was to characterize the savings opportunities associated with high-speed ovens and create a measure package that can effectively leverage those opportunities to guide efficient market utilization of the technology. To accomplish this, the study focused primarily on capturing real-world high-speed oven energy and usage data—both various examples of what is currently being used in foodservice restaurants and high-speed oven replacement for appliances such as convection ovens , which were optimized for energy performance and production. Concrete deliverables for this project included:

- Overview of the current high-speed oven market in California.
- High-speed oven energy and operational use data for ten CFS sites.
- Direct energy and performance comparisons for efficient high-speed oven replacements at three sites.
- A high-speed oven measure package for submission to CalTF.
- Webinar and case study for technical dissemination of research project results, targeted toward utilities, designers, and end users.
- Recommendations for optimal use of existing high-speed oven technologies.

Methodology and Approach

Frontier Energy monitored ovens at 11 CFS sites, including 10 high-speed oven sites and one gas convection oven site, using energy meters connected directly in-line. After at least two weeks of energy data collection, Frontier replaced the ovens at three of the sites (including the gas convection oven site) with efficient high-speed ovens. The team continued energy monitoring following the replacements, using both energy data and interviews with the staff at the sites to capture qualitative takeaways.

Test Sites

The team recruited 11 sites for this research, spanning a variety of use cases but focusing on the most common scenarios, such as cafés serving savory items and quick service restaurants (QSRs). One of the sites featured a gas convection oven, which was replaced with a high-speed oven to evaluate fuel swapping and non-like-for-like replacements. All sites were in California, with a mix of independent smaller shops and much larger chains.

Test Plan

At each of the test sites, Frontier Energy installed an energy meter in-line behind the appliance. All metering was housed inside durable waterproof containment, and the installed meters were securely strapped to ensure that all connections remained stable. Frontier used Continental Control WattNodes paired with Ohio Semitronics current transducers for measuring Wh of electrical consumption and Sensus positive displacement R-275 diaphragm meters for measuring cubic feet of gas consumption, with a maximum time interval of thirty seconds. All installations were conducted at customer specified times and dates to minimize any interruptions to normal operation.

The team conducted measurements for a minimum of two weeks and reviewed the data for quality and consistency prior to metering disconnections. Data was collected at one-minute minimum intervals, as judged necessary to capture the operational cooking patterns exhibited by the high-speed ovens. We then filtered and reviewed that data for repeatability, with any outliers clarified with staff discussions and extending monitoring periods as needed to fully capture the complete scope of normal operation.

Technology Description

High-speed ovens are ovens designed specifically to optimize speed of service: getting food out to customers in the shortest amount of time while maintaining food product quality. High-speed ovens currently fall broadly into the following three categories: microwave, impingement, and combination (combi). The current largest and most well-known subcategory are microwave ovens, which make up the majority of the markets and are most used as front-of-house, ventless appliances in QSRs. They combine microwave heating technology with more traditional heating technologies—such as convection or conduction—to balance the speed of cooking and the texture of the food product, cooking from both the inside and the outside. These oven types typically replace convection ovens and microwaves when added to an existing cookline and can be a compact option for fuel switching from gas to electric, since the amperage requirements are not as high large production electric equipment.

By contrast, impingement high-speed ovens use accelerated hot air to accelerate the external cooking and typically work most effectively on thinner products, like pizzas. These high-speed oven types are gaining traction as more space-efficient replacements for typical conveyor ovens, or for reheating or overflow cooking activities. Due to the quickly evolving nature of the appliance category, the combination high-speed oven category is necessary to capture all the innovations that subvert the ideas of what defines a standard high-speed oven, combining multiple technologies that accelerate cooking performance.

Market Characterization

The California high-speed oven market has expanded significantly over the past decade, thanks to growing awareness of the technology through continued innovations in the appliance category and adoption by some notable big brands. Frontier interviewed stakeholders to update market characterization to reflect current market conditions. Key interview discussion points included the following:

- What equipment types are typically being replace by high-speed ovens, or are high-speed ovens typically being added as new appliances?
- What are the different types of high-speed ovens, and how would you define and differentiate the different categories?
- What are the ideal use cases for each high-speed oven type? When would you specify a high-speed oven vs a different appliance?
- What food products are typically being cooked in a high-speed oven and what is the general expected throughput?
- How fast are high-speed ovens being updated to new versions?
- How will the high-speed oven market evolve in the near future and what sort of inventory changes might be expected? Are there any current market trends?

Key findings Frontier estimates a current inventory of about 23,000 high-speed ovens in the state. Stakeholders expect the high-speed oven market to grow 10 percent to 20 percent over the next two years, with expansions into new sectors, such as convenience stores, that have not yet embraced the technology. High-speeds ovens are also expected to cement their position as a core appliance in cooking lineups for QSRs and large chains with high standardized food products.

Field Monitoring Data

Site 1:

Site 1 is a sandwich chain store with long hours of operation—it is generally open daily from 10:30 a.m. to 8:00 p.m. Site 1 had a 6-kilowatt (kW) high-speed oven as part of its cooking lineup, which had replaced previous iterations of microwaves and ovens in a strategic move to improve speed of service and quality to the customer (McKinley 2025). The high-speed oven is used to toast sandwiches and quickly heat sandwich components, allowing for maximum speed of service. However, not all sandwiches are heated, so this location estimates a typical daily throughput of around 60 sandwiches heated by the high-speed oven.

Frontier Energy conducted electrical monitoring on the high-speed oven and found that it used about 13.1 kilowatt-hours (kWh) and operated for about 10.8 hours per day on average across the monitoring period. While on, the oven was actively cooking for about 13 percent of the total operational time, accounting for 28 percent of the operational energy that the oven consumed. Operational patterns were consistent across the monitoring period and overall usage exhibited clearer differences between peak operational times and periods of longer inactivity. The relatively higher energy consumption rate despite the relatively lower percentage of energy attributed to cooking might also be indicative of higher idle holding temperature at this location.

Site 2:

Site 2 is a café with two locations, serving a variety of coffee, teas, pastries, sandwiches, and snacks. Site 2 generally operates from 7:00 a.m. to 3:00 p.m., seven days a week. Site 2 invested in a high-speed oven to have an all-in-one option for their menu items, allowing them to serve customers quickly without having to install a ventilation hood. This decision was made prior to the opening of the location, in favor of a more traditional convection oven (McCullough 2025). Now, Site 2 uses their high-speed oven to deliver around 200 hot food items to customers daily while operating in the back of house.

Frontier Energy monitored Site 2's existing 6.2kW high-speed oven to evaluate its energy performance. Based on the electrical monitoring, Site 2's high-speed oven operated around 10.8 hours per day, turning on to preheat when staff arrived in the morning to prepare the store for opening, and shutting off at 3:00 p.m. when the shop closed. The high-speed oven operated consistently through the entire monitoring period, averaging 10.0 kWh of energy use per day. Site 2's high-speed oven exhibited cooking activity for about 9 percent of its total operating time, accounting for 33 percent of its total energy use. One unique feature about this dataset was that the monitoring caught a night when the high-speed oven was not shut off, a mistake that resulted in the equivalent of about a full day of extra energy use. This finding illustrates the importance of operator behavior in affecting total energy consumption, and the value of a potential energy saving mode or auto shutdown feature if the oven is inactive for an extended period.

Site 3:

Site 3 is the counterpart second location of Site 2, generally operating from 8:00 a.m. to 4:00 p.m. throughout the entire week and serving a similar menu of cooked items. Like Site 2, Site 3 invested in a high-speed oven during its initial opening to provide customers with a wide selection of hot foods without having to install a ventilation hood. Unlike Site 2, however, Site 3's high-speed oven is in the front of the house.

Frontier Energy monitored Site 3's current 6.2kW high-speed oven to evaluate its energy performance. Based on the electrical monitoring, Site 3's high-speed oven consistently operates around 9.1 hours and averages about 11.1 kWh of energy use per day. Compared to the counterpart location in Site 2, the high-speed oven at Site 3 consumed more energy despite operating for shorter hours, presumably because of more product throughput at this location. Compared to other evaluated sites, the high-speed oven at Site 3 was relatively active, exhibiting cooking activity for about 23 percent of its total operating time. This active cooking accounted for nearly 51 percent of its total energy use, making this unit a good target for potential replacement.

Frontier replaced Site 3's existing 6.2 kW high-speed oven with the modern equivalent for the original older model. The new 6.2kW high-speed oven features more efficient heating technology, along with an energy save mode that can lower idle energy when the oven is not actively in use. Frontier reviewed the energy data of the replacement oven and found that it used an average of 11.0 kWh per day across an average 9.4 hours of operation during the monitoring period after replacement. The average time cooking increased to 26 percent and the energy attributed to cooking increased to 58 percent, which seems to indicate that there may have been a greater operational load during the monitoring period of the replacement high-speed oven compared to the original, The data also indicates that the relative idle rate compared to the cooking rate was reduced with the replacement oven, which would be indicative of the automatic energy save mode taking effect. Overall, savings from the replacement high-speed oven when normalized for hours of operation were a modest 4 percent, though this figure may be a bit higher if more data were gathered over a longer period.

Site 4:

Site 4 is a painting studio that also offers wine and appetizers options as part of its core services, creating a relaxed environment where customers can unwind and paint leisurely. To prepare hot, crispy appetizers for their customers without needing to install a ventilation hood or design a full kitchen space, Site 4 invested in a 4.5-kW high-speed oven (Warren 2025). The operational profile for this high-speed oven is more variable than at most other sites, since Site 4 has more varied operating hours and a different business model with less customer throughput, meaning that the amount of active cooking can vary significantly on a day-to-day basis.

Frontier Energy conducted electrical monitoring on the original high-speed oven and found that it used about 3.3 kWh and operated for about 4.2 hours per day on average across the monitoring period, including days where the high-speed oven was not actively turned on. While operating, the oven was actively used for cooking for about 16 percent of the total operational time, which accounts for 48 percent of the operational energy that the oven consumed. The remaining 51 percent of the energy was used to keep the oven hot and ready for cooking, in case a customer put in a new order. This percentage of energy attributed to cooking was among the highest of the sites reviewed, since the oven was turned on specifically for the limited and well-defined period during which the customers would order food. The oven was generally turned on five to six days a week, with the occasional day without food orders during paint nights.

Frontier replaced this site's existing 20A high-speed oven with the modern equivalent for the original older model. Frontier reviewed the energy data of the replacement oven and found that it used an average of 3.6 kWh per day across an average 4.4 hours of operation during the monitoring period after replacement. The average time cooking during the monitoring period was 9 percent and the percent of energy attributed to cooking dropped sharply to 25 percent. This replacement scenario is indicative of a different usage pattern associated with the monitoring period of new oven, since the oven was used for a similar amount of time but exhibited much less cooking activity. Site 4's cooking demand was among the most variable, since there were a fewer number of customers and they came in discrete baches with long durations, since they were also doing painting onsite. Normalized to operating hours, the new oven actually used 4 percent more energy, despite being used to cook left often. This seems to indicate that the idle energy consumption of the new oven was higher, which may have been due to a higher default idle temperature setting. This replacement scenario illustrates the impact of idle settings on total energy consumption for high-speed ovens.

Site 5:

Site 5 is a bakery chain store with an expansive menu, serving sandwiches, sweet and savory pastries, and a full assortment of drinks and cakes. Site 5's long operating hours begin at 6:00 a.m. and go until 9:00 p.m., seven days a week. To accommodate the throughput for their savory menu items, Site 5 uses a 3.6kW high-speed oven. (Navid 2025)

Frontier Energy monitored the 3.6kW high-speed oven to evaluate its energy performance and observed that it was operating around 14.4 hours per day, notably longer than any of the other sites the team evaluated. During this operational period, the high-speed oven consumed about 11.7 kWh on average per day, though it was only actively cooking for about 6 percent of that time. However, those active cooking periods still accounted for 18 percent of the total daily energy use, so it appears the overall idle rate for this oven was relatively low. This is also evident in that Site 5 was not the site that exhibited the highest energy consumption, despite operating for the longest hours among the sites that weren't convenience stores.

Site 6:

Site 6 is a café operating only during the work week from 7:00 a.m. to 3:00 p.m., to cater to the business crowd. Besides coffee and espresso, this café also offers savory hand pies and sandwiches, thanks to the 6.2kW high-speed oven that they inherited from the former tenant of that space. While other stores from this small coffee chain do not typically have high-speed ovens or any similar counterparts, such as convection ovens, the owners took the opportunity for this location to expand their menu with the high-speed oven available (Aveila 2025).

Based on the electrical monitoring, Site 6's high-speed oven operated around 8.8 hours per day, turning on to preheat when staff arrived in the morning to prepare the store for opening, and shutting off at 3:00 p.m. when the shop closed. The speed oven operated consistently through the entire monitoring period, with no notable trends or variations of note. Across the 8.8 hours of daily operation, Site 6's high-speed oven used an average of 6.4kWh per day, actively heating for about 12 percent of its operating time and idling in a heated ready-to-cook mode for the rest of the time. Active cooking accounted for about 32 percent of total energy use. Since Site 6 was only open during the weekdays, these results were also normalized for the full week to properly compare to the other sites, resulting in an average 4.5kWh per day or energy consumption across 6.3 hours of operation.

Site 7:

Site 7 is a café and bakery that bakes fresh bread to serve daily alongside its drinks and other savory items. The store operates from 9:00 a.m. to 3:00 p.m., five days a week. Site 7 is unique among all the research sites in that it is the only location that did not have a preexisting high-speed oven. Instead, Site 7 uses a four-pan, full-size gas convection oven for its baking needs. Site 7 was included in the study to investigate the potential for fuel substitution possibilities. For this purpose, Frontier Energy conducted an energy analysis on their existing gas convection oven and then switched it out for a 6.5-kW high-speed oven.

The original convection oven was measured to use an average of 33.1 thousand British thermal units per hour and 106 watts (W) across an average 3.4 hours of operation during its days on, used primarily for batch cooking loaves of bread, but also for toasting pastries and baking the occasional entrée like lasagna. Converting this energy consumption to kW for comparative purposes, the convection oven used an equivalent of 9.8kW of energy. Averaging for the full week to include nonoperational days, the oven used 7.5 kWh of energy across 2.8 hours of operation. During discussions with the store owner on how to best utilize the planned high-speed oven replacement, Frontier determined that Site 7 could also replace the majority of its microwave usage. Frontier then also monitored their microwave and observed that it was using an average 0.6 kWh per day.

After the initial monitoring was completed, Frontier installed the 6.5-kW high-speed oven, which had a smaller capacity but a faster cook time than the convection oven. The owner was given access to a knowledgeable high-speed oven representative to learn how to best use the oven, and monitoring commenced with the request that all possible cooking demand be shifted from the convection oven and microwave to the high-speed oven. Since this was a technological shift with a learning curve however, the original appliances were also left in the kitchen to provide a backup option and prevent any negative outcomes for their operation.

The staff was pleased to have a new cooking option, which had half the capacity but cooked twice as fast as the existing convection oven. However, despite the initial training given, there were still difficulties in transitioning all of the cooking to the high-speed oven. The energy monitoring captured the high-speed oven being used seemingly only for the batch baking of bread, illustrated by how 86 percent of the high-speed oven's energy use was attributed to cooking, more than triple that of any other monitored site. Energy attributed to cooking was 98 percent of all energy used, so the site's usage profile for the high-speed oven had nearly no idling, which was different from every other site observed.

Total appliance usage also jumped significantly, with the convection oven being used significantly more after the installation of the high-speed oven than it had previously. This was a result of both greater demand for those days of operations and experimentation with learning how to use the high-speed oven. (Gastelumendi 2025). On days that the business was open, average convection oven usage was the equivalent of 10.3 kWh, up 6 percent from the 9.7 kWh average from before the high-speed oven was installed. Microwave usage dropped slightly for 629W to 599W, which may be indicative of some minor movement of microwave activity shifted to the speed oven but is more likely to just be natural variance in a period of volatile business activity. Meanwhile, high-speed oven energy consumption only averaged 2.2 kWh across 1.8 hours of operation.

This replacement scenario unfortunately does not tell us very much about the energy impacts of switching from convection ovens and microwaves to high-speed ovens. What it instead illustrates is the arduous process needed to fully integrate new technologies into a foodservice operation, which can take multiple months, repeated training sessions, and dedication to making the switch. This can be extremely difficult in the foodservice world, with time-sensitive customer demands and thin margins. It also parallels other new technology adoption efforts that have come in the foodservice space, which tend to be relatively slow until a strong incentive emerges. More data and a longer monitoring timeline is necessary to properly evaluate fuel switching and convection oven/microwave replacement scenarios, which Frontier suggests as a topic for future research.

Site 8:

Sites 8 through 11 are stores in a large convenience store chain, which are unique compared to the other sites because they operate for 24 hours a day. This convenience store chain uses its high-speed oven for its quick service hot food items, quickly providing hot items straight to the customer. Frontier Energy conducted energy monitoring on the high-speed oven at Site 8 and found that it used an average of 23.5 kWh per day.

While significantly more energy consumption than any of the non-24-hour sites evaluated in this study, the energy when normalized per hour of operation was relatively on par with those other sites.

The high-speed oven operated at an average 0.98 kW input rate and was actively cooking for about 8 percent of its total time on. Active cooking energy accounted for 20 percent of the total energy use.

Site 9:

Frontier Energy conducted energy monitoring on Site 9's high-speed oven and found that it used an average of 25.8 kWh per day across its 24-hour operating period. The oven never fully turns off but is only actively cooking for about 7 percent of its time on, which accounts for 22 percent of its total energy use. Compared to the chain's other locations, Site 9 seemed to be operating their high-speed oven at a lower idle rate, since cooking energy accounted for a larger percentage of total energy use despite Site 9 having the lowest cooking activity amongst the chain store's locations.

Site 10:

Frontier Energy conducted energy monitoring on Site 10's high-speed oven and found that it used an average of 31.2 kWh per day across its 24-hour operating period. The oven operated similarly to those at Site 8 and 9 in that it was only actively cooking for about 8 percent of its time on and that the cooking energy accounted for about 20 percent of its total energy use. However, when compared to the other sites, Site 9 had a significantly higher daily energy consumption, which seems to indicate that the oven was operating at a higher idle rate.

Site 11:

Frontier Energy conducted energy monitoring on Site 11's high-speed oven and found that it used an average of 36.2 kWh per day across its 24-hour operating period, which was the highest among any of the high-speed ovens sites. Site 11 also had the highest average input rate, operating at an average 1.5 kW despite only cooking for 11 percent of the total operational time. Active cooking accounted for 24 percent of the total energy consumption.

Findings and Results

Based on market research, Frontier estimates a current inventory of about 23,000 high-speed ovens in the state of California. High-speed ovens have been growing significantly, and stakeholders have noted that the market is expected to grow 10-20% over the next two years, a sentiment echoed by both the supply and demand side.

High-speed ovens currently have the largest presence in QSRs, where speed is the top priority and taste is important, but secondary. Its key competitive advantages lie in its small footprint, its speed for single-batch cooks, and its ability to generally operate without a ventilation hood. For those reasons, high-speed ovens are most commonly used at the front of house; this was made abundantly clear in the site recruitment process for this project, where well over 90 percent of the sites with existing high-speed ovens used them in the front of house.

High-speed ovens are highly versatile and can work well as a flexible appliance to cover periods of high demand, but they excel most in quickly reheating pre-prepared, highly standardized food product. Because these ovens operate at such high-speeds and temperatures, they work best when the product composition of the food cooked is well known and highly standardized, since cooking results can differ significantly within a matter of seconds. High-speeds ovens also cater to this market by often having programmable menus that can be effectively used without any skilled cooking labor.

For these same reasons, high-speed ovens are still developing a foothold for back-of-the-house applications, such as full-service restaurants, which more often involve differing portion sizes or ingredients. When no two plates are exactly the same, restaurants tend to prefer slower, more forgiving methods that maximize quality of the ingredients. Often, if a ventless appliance is needed or desired, restauranteurs will lean towards ventless combis as a preferred alternative instead. Where high-speed ovens benefit is when there are no available existing drains and/or water connections, which make combi ovens more difficult to specify for the space. In those instances, high-speed ovens may sometimes find a place in the back of the house, replacing other finishing appliances, such as salamander broilers, toasters, or panini presses.

However, high-speed ovens face other barriers of adoption, such as the high electric requirements that many older foodservice facilities might not possess. Electrical upgrade costs—if necessary for installation—could also make high-speed ovens cost prohibitive. High-speed ovens may also have to deal with hidden fees for ventless installation, with one designer citing a standard benchmark of $5,000 in costs for the permitting work and engineering drawings needed to specify a high-speed oven for a ventless operation (McDonnell 2025). Despite growing awareness and market share for high-speed ovens, this is a cost that is not expected to go away, paralleling engineering drawing requirements even for classic standardized equipment, such as walk-in freezers.

Energy Savings Opportunities

Real-world operational data from this project has shown that there is significant variation across use cases for high-speed ovens, with highly varying hours of operation, average daily energy consumption, and duty cycles observed across the eleven sites monitored. These differences could be more than two-fold and did not show a consistent pattern even when normalizing for energy consumption over time, indicating that a large body of data is needed to generate reliable conclusions. Despite large differences between behaviors of high-speed ovens at different sites and applications however, each individually observed high-speed oven operated fairly consistently on a day-to-day basis. The observed high-speed ovens generally only deviated from their average daily energy consumption by 10% on any given day, so for many sites, conclusions seemed like they could be quickly and reliably drawn on an oven's operational profiles with just a week of data. Detailed results for the operational data gathered for the eleven sites are summarized in Table 3 below, with references and equipment detailed compiled in Table 1 and Table 2.

Table 1: Site and Oven Reference Guide

Site #	Business Type	Baseline Oven #	Replacement Oven #
1	Sandwich Shop	1	-
2	Coffee Shop 1 Site 1	2	-

Site #	Business Type	Baseline Oven #	Replacement Oven #
3/3R	Coffee Shop 1 Site 2	2	7
4/4R	Tavern / Art Gallery	3	8
5	Patisserie	4	-
6	Coffee Shop 2	2	-
7/7R	Bakery & Restaurant	10	9
8	Convenience Store Site 1	5	-
9	Convenience Store Site 1	5	-
10	Convenience Store Site 1	6	-
11	Convenience Store Site 1	6	-

Table 2: Oven Technical Specification Guide

Oven #	Oven Specs
1	208/240V, 1 Phase 30 Amps, 6000 Watts
2	208/240V, 1 Phase 30 Amp, 6200 Watts
3	208/240, 1 Phase 20 Amps, 4500 watts
4	208/240V, 1 Phase 20 amps, 3600 Watts
5	204/208V, 1Phase, 30 Amps, 6675 Watts
6	204/208V, 1Phase, 30 Amps, 6675 Watts
7	208/240V, 1 Phase, 30 Amps, 6200 Watts
8	208/240V, 1 Phase, 20 Amps, 3680 Watts

Oven #	Oven Specs
9	208/240V, 1 Phase 17 Amps, 6500 Watts
10	33,000 BTU/h Gas Convection Oven

Table 3: Site equipment, energy use, and operating hours.

Site	Equipment	Average Daily Energy Use (kWh)	Average Daily Operating Hours (h)	Average Input Rate (kW)	Average Cooking Duty Cycle (%)	Percent Energy Attributed to Cooking (%)
Site 1	Oven #1	13.1	10.8	1.21	12.5%	27.7%
Site 2	Oven #2	10.0	10.8	0.93	9.3%	32.6%
Site 3	Oven #2	11.1	9.1	1.22	23.2%	51.0%
Site 3R	Oven #7	11.0	9.4	1.17	25.7%	58.1%
Site 4	Oven #3	3.3	4.2	0.77	15.9%	47.6%
Site 4R	Oven #8	3.6	4.4	0.81	9.0%	25.3%
Site 5	Oven #4	11.7	14.4	0.82	6.4%	18.2%
Site 6	Oven #2	4.5	6.3	0.71	12.3%	31.5%
Site 7*	Oven #10	7.5	2.8	2.69	N/A	N/A

Site	Equipment	Average Daily Energy Use (kWh)	Average Daily Operating Hours (h)	Average Input Rate (kW)	Average Cooking Duty Cycle (%)	Percent Energy Attributed to Cooking (%)
Site 7R*	Oven #9	7.8	2.4	3.27	86.2%	97.7%
Site 8	Oven #5	36.2	24.0	1.51	10.8%	23.3%
Site 9	Oven #5	13.0	10.4	1.26	7.1%	18.4%
Site 10	Oven #6	25.8	23.9	1.08	6.8%	21.9%
Site 11	Oven #6	31.2	23.8	1.31	7.4%	20.0%

*Site 7 values represent the sum of energy consumed by the convection oven, microwave and high-speed oven (replacement only)

The monitored sites had a wide range of daily energy consumption depending on the business's operating hours. The monitored high-speed ovens on average had a daily energy use of 14.5 kWh, operating for 12.6 hours at an average input rate of 1.1 kW. The monitored ovens were cooking for about 12 percent of their total operating time on average, accounting for about 31 percent of their total energy use. Table 4 below shows the average energy consumption per day of the week at each site. Most sites had busy days and slower days, and energy consumption is separated by day of week in this chart to prevent averages from being skewed by these variations in traffic and days when locations are closed.

Table 4: Heatmap of Average Energy Consumption, By Day of Week (Wh), Including Replacement Ovens

Site # >	1	2	3	3R	4	4R	5	6	7	7R	8	9	10	11
Sunday	11994	9213	10502	10967	2971	5707	10636	252	10026	19755	35045	12784	24971	30060
Monday	13303	8599	10512	10360	1313	2953	12197	5181	7	253	35972	12028	25607	31551
Tuesday	13323	9178	10547	10974	805	2882	11491	6340	7	253	37242	12225	26595	31409
Wednesday	13299	9614	10766	10576	4568	3896	12370	6470	7232	18837	35855	8199	26296	29931
Thursday	13677	11772	11044	10195	2212	95	9399	6594	12121	844	36934	13956	24989	30968

Friday	12974	11254	11334	10966	3121	3440	11967	6217	16393	9099	36544	17361	26365	32646
Saturday	12964	10358	12804	12965	8033	5980	14024	253	6381	5210	35860	14720	25726	31531

Table 5 below shows the average energy consumption per day of the week of each speed oven when idling, between heating food items. This shows how well each site utilized their oven, with the least productive sites using up to 90% of energy consumed on idling and only 10% of energy consumed on producing food for customers. In contrast, the most productive sites spent only 29-57% of energy consumed on idling because their oven was frequently heating food for customers and was turned off during slow periods.

Table 5: Heatmap of Portion of Energy Consumption Spent on Idling, By Day of Week (%), Including Replacement Ovens

Site # >	1	2	3	3R	4	4R	5	6	8	9	10	11
Sunday	73.1	60.4	41.8	34.0	45.0	74.5	79.8	-	82.6	86.6	84.7	86.8
Monday	72.4	72.3	53.6	47.3	56.8	78.2	83.9	68.8	78.2	78.5	75.5	81.0
Tuesday	71.2	73.6	53.7	42.6	54.1	75.5	86.2	71.3	71.9	77.4	74.9	80.1
Wednesday	77.6	67.4	52.7	47.4	58.5	82.3	83.5	65.8	77.6	77.1	75.9	78.0
Thursday	70.0	71.0	53.5	51.3	44.6	-	79.9	66.1	73.9	80.7	80.4	75.6
Friday	70.8	70.6	48.3	41.5	54.0	53.0	74.4	70.5	74.3	80.7	74.5	76.6
Saturday	70.8	56.2	39.6	28.9	53.7	59.7	85.0	-	78.1	90.2	80.8	81.8

Figure 1 and Figure 2 below compare the average energy consumption of the high-speed ovens monitored at each site, grouped by day of the week. The data is separated by day of the week to prevent the averages from being skewed by fluctuations in business across the week and days when businesses are closed. The 24-hour convenience stores used twice as much energy as the other sites because the ovens were rarely turned off. They have been moved into a separate graph to prevent compression of the bars representing the business that are not open 24 hours a day.

Figure 1: QSR High-Speed Oven Average Energy Consumption

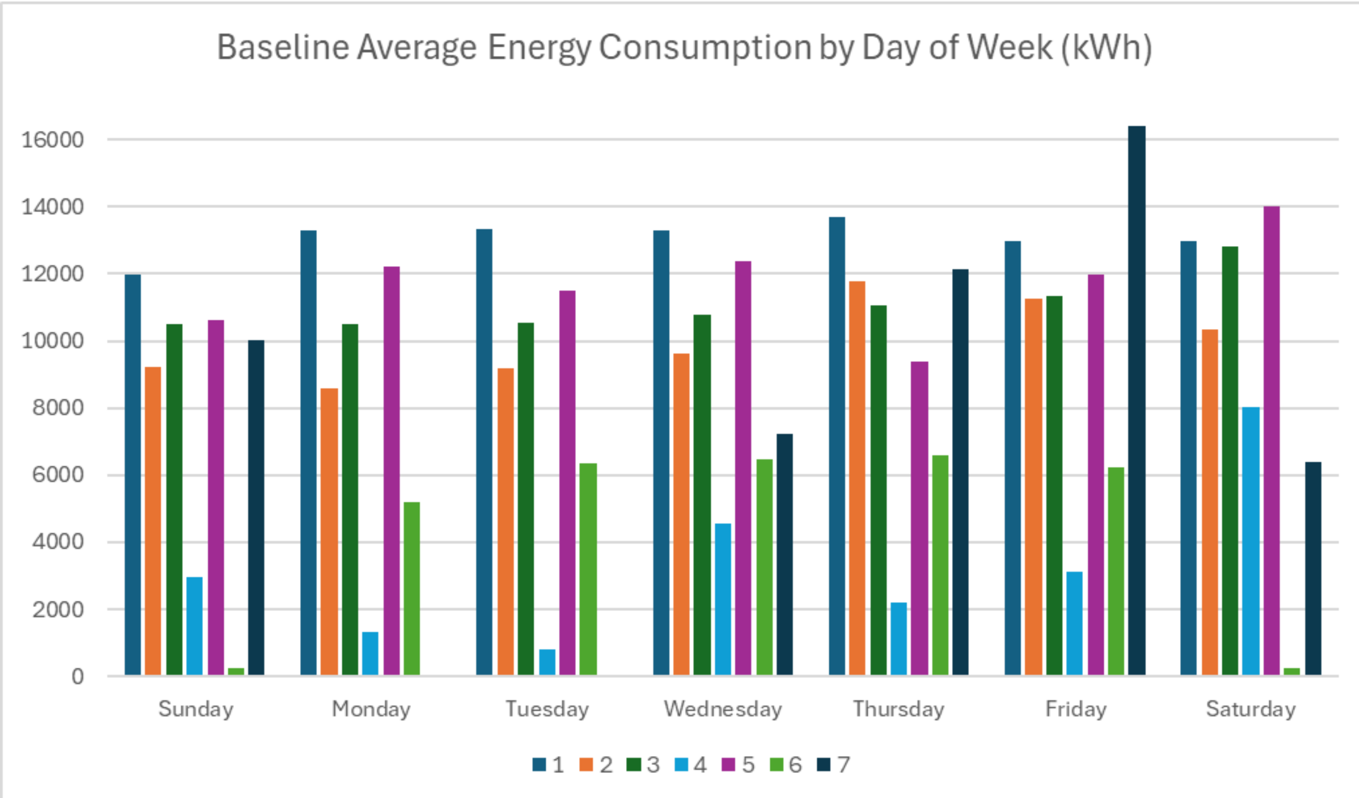
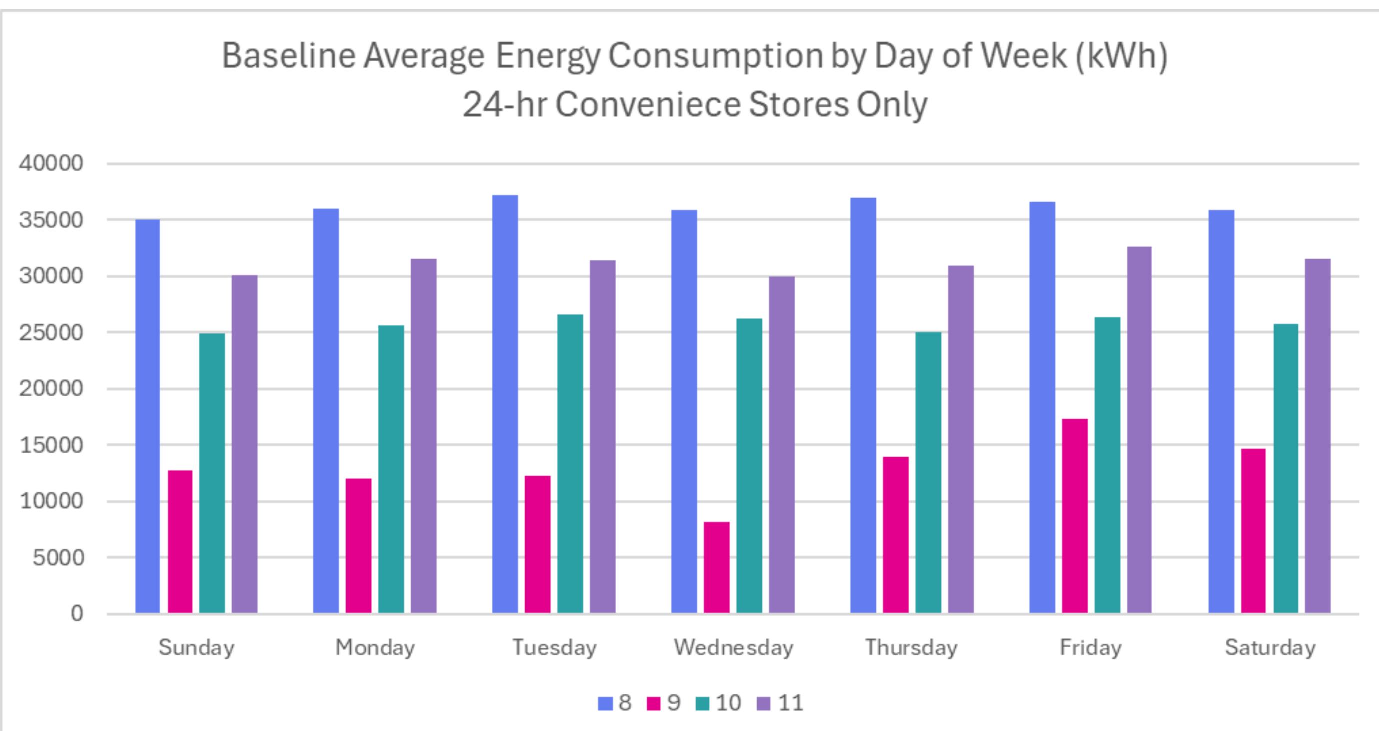


Figure 2: Convenience Store High-Speed Oven Average Energy Consumption



The heatmap below compares the heating energy use to the idling energy use within sites, rather than between sites. The heating energy use can be thought of as productive energy use, when the oven is being used to produce food to sell to customers. This heatmap helps to visualize which sites are effectively using their speed ovens and which are underutilizing their ovens. Only sites 3 and 4 have any days where they use more energy heating food than idling. All other sites use far more energy idling than producing food. This shows the possibilities for energy savings by implementing special holding modes to reduce energy during slow periods or better insulating ovens, so they require less energy input to maintain temperature while idling.

Table 6: Heatmap of Average Energy Spent Heating vs. Idling, By Day of Week (Baseline and Replacement Ovens Included)

	Heating Energy Use (Wh)											
Site # >	1	2	3	3R	4	4R	5	6	8	9	10	11
Sunday	3207	3580	6036	6621	1576	1435	2126	-	6105	1693	3832	3955
Monday	3647	2340	4825	5240	517	624	1947	1559	7854	2554	6282	6004
Tuesday	3825	2380	4829	5004	399	687	1572	1774	10451	2725	6684	6243
Wednesday	2970	3077	5030	5137	1857	676	1946	2156	8048	1831	6345	6586
Thursday	4081	3371	5080	4539	1164	-	2383	2183	9651	2664	4892	7548
Friday	3758	3267	5792	5639	1387	1580	3565	1786	9405	3338	6729	7623
Saturday	3765	4468	7660	7532	3684	2380	1835	-	7849	1423	4947	5737
	Idling Energy Use (Wh)											
	1	2	3	3R	4	4R	5	6	8	9	10	11
Sunday	8712	5463	4335	3558	1288	4202	8376	-	28940	10938	21139	26105
Monday	9585	6094	5562	4805	679	2236	10141	3444	28119	9302	19321	25547
Tuesday	9443	6634	5589	5176	470	2116	9809	4403	26791	9327	19911	25166
Wednesday	10289	6372	5605	5267	2617	3147	9881	4156	27807	6160	19951	23332
Thursday	9535	8267	5842	5104	939	-	9472	4254	27284	11139	20097	23410
Friday	9131	7845	5421	4396	1629	1779	10368	4268	27139	13922	19636	25023
Saturday	9118	5723	5023	4353	4272	3529	10436	-	28011	13161	20779	25794

Table 7 shows the vampire load (power draw when the unit is powered off) of the baseline and replacement speed ovens at each site that was monitored. There is a wide spread of performance between units. Interestingly, there are some minor differences between identical models of speed oven at different sites. The greatest differences apparent are between ovens from different manufacturers, with models by some manufacturers drawing twice as much when powered off as similar models from other manufacturers. This discovery shows a small but worthwhile potential for energy savings with the inclusion of technology in future designs to limit this vampire draw or fully disconnect the unit from main power when turned off.

Table 7: Heatmap of Average Vampire Load, By Day of Week (W)

Site # >	1	2	3	3R	4	4R	5	6	8	9	10	11	7R
Oven # >	1	2	2	7	3	8	4	2	5	5	6	6	9
Sunday	5.3	12.0	8.4	14.4	5.3	4.2	11.6	10.5	N/A	11.3	N/A	N/A	5.1
Monday	5.4	12.0	8.4	12.4	5.3	4.7	11.6	10.6	N/A	11.5	9.5	N/A	5.1
Tuesday	4.2	12.0	8.6	12.3	5.3	3.8	11.0	11.0	N/A	11.6	N/A	N/A	5.1
Wednesday	3.2	12.0	8.7	12.3	5.3	3.8	11.2	10.6	N/A	11.6	N/A	15.3	3.1
Thursday	4.8	12.0	8.4	8.8	5.2	3.9	11.5	10.7	N/A	11.4	N/A	13.9	5.1
Friday	6.3	12.0	8.3	12.4	5.3	3.9	10.9	10.9	N/A	11.4	N/A	N/A	5.1
Saturday	6.1	12.0	8.4	12.9	5.3	4.4	11.2	10.5	N/A	11.5	N/A	N/A	5.1

Frontier conducted high-speed oven replacements at three sites, replacing two preexisting high-speed ovens and one gas convection oven at the sites denoted with "R" in Table 3. The selected high-speed oven replacements represented the newest high-speed ovens that best suited the cooking needs of the foodservice operations they went into. Findings from the high-speed oven replacements were mixed. The replacement at Site 3 provided the most reliable data, since the site's day-to-day usage profiles were steady and the staff already had experience with a high-speed oven from the same manufacturer. The high-speed oven replacement at Site 3 showed a 4% energy savings when normalized for hours of operation. Data from the high-speed oven replacement at Site 4 showed the opposite result with a 4% increase in energy, but the large shift in the idle and cooking components of the high-speed oven's operational activity patterns suggests that there may have been confounding factors stemming from demand variations during the monitoring period. Site 4 would have benefitted from additional monitoring time, to ensure that its more inconsistent operational patterns could be properly characterized. Site 7 similarly would have benefitted from a longer monitoring period, though much longer would have been needed to allow the staff to fully implement the transition of all of their cooking activities from their convection oven and microwave to the new high-speed oven. A technology change requires continuous training and experimentation, which is difficult to balance with running a full-time business. Results from Site 7 are inconclusive at this time. Compared to the proposed measure criteria, all replacement ovens seemed to operate within the idle rate cap of 1kW, though the cooking energy efficiency could not be evaluated in real-world foodservice operations.

Frontier also created an energy model as outlined in Table 8 below, combining real-world operational data gathered from this study and the previous CEC Plug Load study (Ruan, Finck and Livchak 2021) with laboratory test data generated from Frontier Energy's Food Service Tech Center, through standardized testing of high-speed ovens under ASTM F2238 Standard Test Method for Performance of Rapid Cook Ovens.

Table 8: High-speed oven energy model

Assumptions	Base Case Model	Measure Case Model	Source
Idle Energy Rate (kW)	1.37	0.81	Averaged from Lab Data
Cooking Rate (kW)	4.8	4.9	Averaged from Lab Data
Preheat Energy (kWh)	0.90	0.92	Averaged from Lab Data
Preheat Time (hrs)	0.21	0.24	Averaged from Lab Data
Estimated Daily Hours of Idle (Hours/Day)	12.28	12.28	Derived from Field Data
Estimated Daily Hours of Cooking (Hours/Day)	1.37	1.34	Derived from Field Data
Estimated Daily Preheat Events (Preheat Energy Events/Day)	1	1	Derived from Field Data
Estimated Daily Hours On (Hours/Day)	13.86	13.86	Derived from Field Data
Operating Days/Year (days)	344	344	Derived from Field Data
Preheat Energy Per Day (kWh)	0.90	0.92	Calculation
Idle Energy Per Day (kWh)	16.86	9.96	Calculation
Cooking Energy Per Day (kWh)	6.52	6.54	Calculation
Daily Energy Consumption (kWh)	24.27	17.42	Calculation
Annual Energy Consumption (kWh)	8,346	5,991	Calculation
Average Demand (kW)	1.75	1.26	Calculation
Annual Energy Savings (kWh/yr)	2,354		Calculation

Assumptions	Base Case Model	Measure Case Model	Source
Percent Savings (%)	28.2%		Calculation

The resulting analysis exhibits the potential for about 28 percent energy savings when converting from a standard high-speed oven to an energy efficient high-speed oven, equivalent to 2,354 kWh per replaced unit. With a current inventory of about 23,000 high-speed ovens in California, Frontier estimates that the statewide energy savings potential for high-speed ovens may be around 5.4 terawatt-hours (TWh) per year, assuming that 10 percent of the existing high-speed oven inventory are older units ready for replacement.

Return on Investment

Frontier Energy reviewed the current high-speed oven market to determine the incremental measure cost between baseline and efficient high-speed ovens, as determined via laboratory testing using ASTM F2238. Any high-speed ovens that had not been tested as specifically passing the proposed high-speed oven criteria were assumed to be baseline units for the purpose of this evaluation, which produced the cost chart shown in Table 9.

Table 9: High-speed oven current market cost chart.

Category	Reviwed Price Range	Average Equipment Cost ($)
Baseline	$3,979 - $18,493	$9,506
Efficient	$11,382 - $13,466	$ 12,485

Using this chart, Frontier Energy calculated an incremental measure cost of $2,979 for upgrading from a baseline high-speed oven to an efficient one. With a calculated 2,354 kWh per year of savings, as previously presented, and assuming an average commercial cost of electricity in California of 30 cents per kWh, this results in an estimated return on investment (ROI) of 4.2 years.

Measure Development

Using the data collected throughout the course of this research project and combining it with previous field data and laboratory collected throughout years of testing using ASTM F2238, Frontier Energy has developed a proposed measure package for high-speed ovens. This measure package was composed in large part using information from the field data, energy model, and incremental measure cost analysis outlined in previous sections of this report, and will be submitted to the California Technical Forum for review. Proposed measure criteria for high-speed ovens is an idle rate ≤ 1 kW and a cooking efficiency ≥ 39%.

Measure Package Data

Stakeholder Feedback

Frontier Energy engaged manufacturers, representative groups, designers, consultants, and associations to advise the outlook on the high-speed oven market in California. Stakeholders were initially contacted through email outreach and discussion, which later progressed to verbal interviews where availability and interest allowed. Stakeholders that contributed in this manner included:

- NAFEM
- McDonnell Design
- Inform Foodservice
- Foodservice Equipment Agents
- High-Speed Oven Manufacturers

These discussions shaped the way Frontier Energy approached the research and the measure package. Stakeholders have noted sizeable additional growth potential in the market and are curious as to how a potential measure will be implemented, as no singular definition of high-speed ovens and its subcategories has yet been widely adopted. At the time of this report's writing, there is only sufficient data to support a like-for-like replacement scenario for high-speed ovens, but future research will hopefully support other replacement scenarios—such as for convection ovens, as was demonstrated in one instance through this study.

Recommendations

From unanimous stakeholder projections on market growth, this project has shown that there is a significant demand for high-speed ovens, which fill the important niche of a fast, flexible cooking appliance that does not require a ventilation hood. High-speed oven technology expands the capabilities of businesses whose core business models do not revolve around full meals, at times improving the food quality as an upgrade to existing appliances or otherwise expanding the menu for businesses that might not otherwise sell hot items. Site 4's story also demonstrated the more niche case where a high-speed oven may be the optimal path to operating as a foodservice facility, which allowed the business to expand operating hours and clientele to improve its business model. Businesses reading this report can determine whether this technology is right for them by referring to the field monitoring data section, which provides numerous examples of how high-speed ovens were integrated into various business models and types of foodservice operations.

For businesses interested in investing in high-speed ovens, this research elucidates the pros, cons, and potential savings of high-speed oven technology over other options. This project has also created a draft measure package for high-speed ovens, illustrating the difference between baseline and efficient models and setting the stage for potential rebates and wider industry support for adoption of the technology. Utilities and other rebate programs will hopefully look at this research to verify the savings potential of these appliances and consider adding high-speed ovens to their repertoire of efficiency offerings.

The data collected throughout the duration of this project was focused directly on high-speed ovens, as they commonly exist within the current market landscape; it is representative of the most prevalent use cases in California. Feedback from this research has shown that high-speed ovens are primarily installed at facilities that want to serve hot and fresh savory items without having to install a ventilation system or deal with the associated foodprint. This means that when not replacing an existing high-speed oven, high-speed ovens are most often being installed in place of countertop convection ovens, toasters, microwaves, or some combination of these appliances.

This research covers the use case of replacing a high-speed oven and provides limited insight into potential cases for fuel-switching with a gas convection oven, but it does not cover the full gamut of potential replacement cases. Additionally, the three replacements conducted during the project did not replicate the theoretical savings represented by the energy model. Follow-up research on real-world replacements for high-speed ovens and other countertop appliances is recommended for more comprehensive support of energy savings projections. For additional field studies for different replacement scenarios, long monitoring periods with extensive staff training is highly recommended to ensure the full transition process is properly captured.

References

ASTM International. 2020. "Standard Test Method for Performance of Rapid Cook Ovens." *ASTM F26.06.* ASTM International.

Booth, Kyle. 2022. *Rapid Cook Oven Measure Study.* Energy Solutions.